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The use of geo-tube method to retard the migration of contaminants in dredged soil

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ABSTRACT: In order to examine the applicability of geo-tube method as containment system for contaminated sediment, several laboratory experiments were carried out. The Containment Efficiency (CE) value was defined to evaluate the performance of geo-tube for containment. The conclusion of the experiments and interpretation is as follows. (1) The contaminants in drainage from geo-tube rapidly decreased at the initial stage of the dewatering process. (2) The CE was greater than 99.8% when adding flocculant. The most of contaminants were successfully trapped in the geo-tube. (3) The CE was not affected by content of contaminants in the soil of the same grain size distribution. (4) The CE was improved when adding the flocculant. From these results, it is concluded that geo-tube method is an effective containment system for contaminated sediment.

1. INTRODUCTION

In Japan, administrative offices of water areas continuously dredge to maintain water depth for flood control, ships and the environment. However, in the course of dredging, they sometimes encounter contaminated sediment. For example, in Minamata and Tokuyama, there were mercury contaminated sediments that originated from industrial waste drainage. Also, in Ichikawa and Toyama, there are dioxins contaminated sediments. In such cases, to reduce its environmental risks, it is necessary for an administrative office to carry out an appropriate countermeasure. The best solution is to remedy contaminated sediment immediately, but with current technologies it takes a lot of money and time to remedy a large volume of contaminated sediment.

Geo-tube method is proposed as one of containment system for contaminated dredged sediment (Figure1, Photo1). The method has three merits[1], high speed dewatering, clean drainage and efficient construction. It can be an inexpensive short-term containment method. FHHA[2] suggested geotextile's mechanism of filtration. Young et.[3] suggested utilizing a geosynthetic fabric container (GFC) to contain contaminated dredged sediment.

This paper reports the results of laboratory experiments of the geo-tube performance with respect to the migration of contaminants in dredged soil[4].

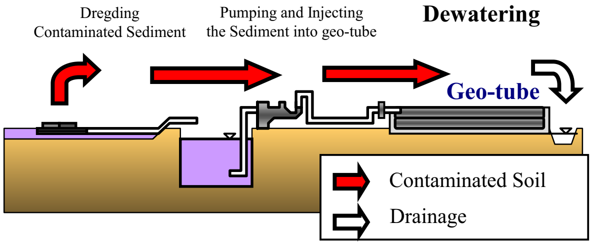

Figure1 Construction Image of a Containment System

Photo1 The Geo-tube Method

2. MATERIALS & METHODS

2.1 Materials

2.1.1 Soil Sample

Soil samples were taken from two different contaminated sites and sieved to remove gravels larger than 20mm. One is contaminated with arsenic, lead and polychlorinated biphenyl (Sample 1) and the other is contaminated with dioxins (Sample 2). Clean sands were added to Sample 2 to prepare a sample of lower dioxins content (Sample 3). Physical properties and content of contaminants of these samples are shown in Table 1. Grain size distribution was presented in Figure 2.

Table 1 Result of Soil Tests and Content Test

	Specific gravity	Water Content (%)	Liquid Limit (%)	Ignition Loss (%)	Content: Average of 2 samples As (mg/kg)	Pb (mg/kg)	PCB (mg/kg)	Dioxins (pg-TEQ/g)
Sample 1	2.607	27.6	39.7	9.85	16.5	194.5	3.5	-
Sample 2	2.665	66.3	51.7	6.63	-	-	-	71,500
Sample 3	2.64	20.96	-	1.67	-	-	-	3,600

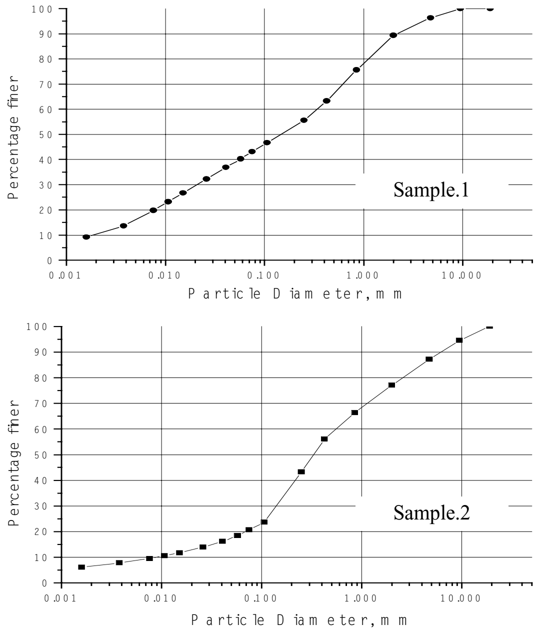

Figure 2 Grain size distribution

From the results of leaching tests, it was noted that the contaminants in the samples were hard to dissolve in water and remained to adhere to the soil grains. Figures 3abc show the content of lead, arsenic and polychlorinated biphenyl by grain size for Sample 1. For the most part, lead and polychlorinated biphenyl adhered to fine grains, silt2 and clay, while arsenic tended to stick to gravel as well as silt1, silt2 and clay. The content of dioxins by grain size for Sample 2 was given in Figure 3d, showing that major percentage of dioxins adhere to fine grains.

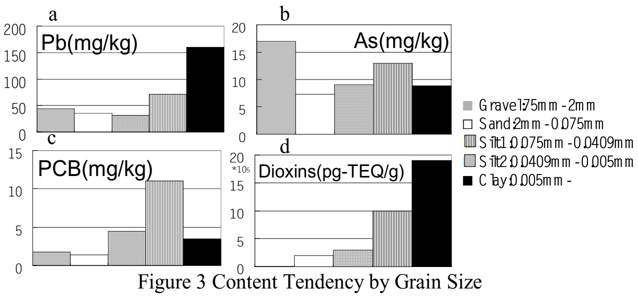

Figure 3 Content Tendency by Grain Size

2.1.2 Geotextiles

Geo-tubes of 0.02m^3 and 0.2m^3 were made of one layer of geotextiles. A pressure filtration test was performed on the geotextiles. Properties and performance of filtration of the geotextiles are shown in Table2.

Table2 Result of Pressure Filtration Test

Textile	Thick-ness (mm)	Mass (g/m2)	Permittivity (cm/S)	Turbidity at No-Pressure	Turbidity at 10kPa
Geotextile 1 (Woven)	0.35	210	$4.82*10^{-3}$	25.5	64.8
Geotextile 2 (Non-Woven)	3.0	300	$7.00*10^{-1}$	596	27,600
Textile (Woven)	0.45	-	-	43.1	383
Textile (Non-Woven)	3.5	595	-	1,490	44,100

Turbidity can be the criterion for choosing the appropriate textile for the geo-tube, because the most contaminants in the samples stick to soil grains. As preventing soil grains to pass through geotextiles is the important mechanism, Geotextile 1 was used for making geo-tubes in the experiments.

2.2 Test procedures

Experiments were performed as follows:

1) Tapped water was added to all the samples to prepare slurry with water content of 600%. For some test cases, flocculant was added to the slurry in order to encourage fine fractions to cohere.
2) The slurry was injected to a geotextile bag (geo-tube). For a geo-tube of 0.2m^3, an electrical pump was used for the injection.
3) The geo-tube filled with slurry was left for several hours until the drainage was practically completed. The content of contaminants in the drained water was examined.

Type of sample, size of geo-tube and flocculant were taken as test parameters for the study of those effects. Test conditions are summarized in Table 3.

Table 3 Test conditions

Case	Sample	Size	Flocculant
1	1 (Pb, As, PCB)	0.02m^3	-
2	1 (Pb, As, PCB)	0.02m^3	Add
3	1 (Pb, As, PCB)	0.2m^3	Add
4	2 (dioxins, higher content)	0.02m^3	-
5	2 (dioxins, higher content)	0.02m^3	Add
6	3 (dioxins, lower content)	0.02m^3	Add

3. RESULTS

Water of approximately 10 liters and 90 liters was drained from the geo-tube of 0.02m^3 (Case 1 and 2) and 0.2m^3 (Case 3) respectively. The contents of contaminants in the drained water are plotted against the amount of drainage in Figures 4, 5 and 6, in which the allowance values in Japanese environmental standard and N.D., non-detected, are indicated. In most test cases, the content of contaminants fell below the value specified in the Japanese environmental standard after the drainage of about 5 to 10 liters almost irrespective to the total amount of drainage corresponding to the size of geo-tubes. Case 2 shows lower content of contaminants overall than Case 1, indicating that by adding appropriate flocculant to the slurry, the performance of geo-tube's filtration improves.

Results of Case 4 to 6 are presented in Figure 6, showing that the content of dioxins decreased with the process of drainage in all the cases. The addition of flocculant clearly improved the performance of the geo-tube's filtration.

4. INTERPRETATION OF RESULTS

4.1 Evaluation of Applicability

To evaluate the applicability of geo-tube method to retard migration of contaminants, two indexes were defined, Filtration Efficiency (FE) and Containment Efficiency (CE). FE accounts for the performance of geo-tube's filtration for containment at a point in time and CE accounts for the performance of geo-tube for containment in the overall dewatering process.

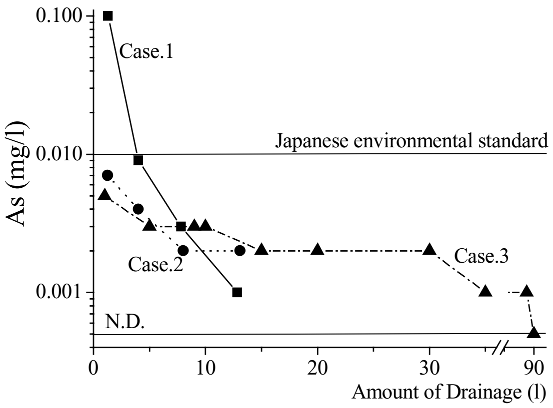

Figure 4 Content of arsenic in the drainage

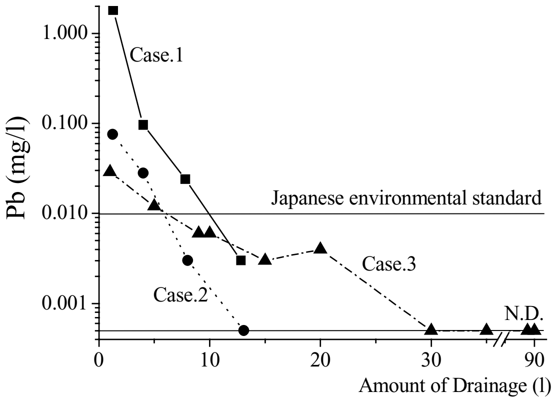

Figure 5 Content of lead in the drainage

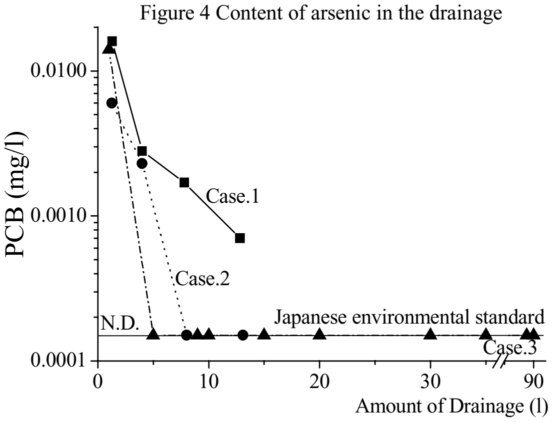

Figure 6 Content of PCB in the drainage

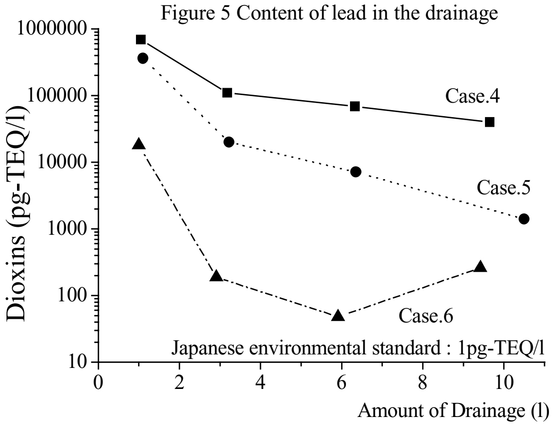

Figure 7 Content of dioxins in the drainage

4.2 Containment Efficiency

4.2.1 Filtration Efficiency

The filtration efficiency (FE) is determined as the ratio of the current content of contaminants in the drainage to the initial content of contaminants in injected slurry.

$$FE = \frac{c_{initial} - c_i}{c_{initial}} \times 100 \cdots\cdots (1)$$

$$c_{initial} = \frac{c_s \cdot \gamma_w}{\frac{w}{100} + \frac{1}{G_s}} \cdots\cdots (2)$$

FE : Filtration Efficiency (%)

$c_{initial}$: content of contaminants in initial slurry (mg/L or pg - TEQ/L)

c_i : current content of contaminants in drainage (mg/L or pg - TEQ/L)

c_s : content of contaminants in soil (mg/kg or pg - TEQ/g)

w : water content of dredged soil (%)

G_s : specific gravity of soil

γ_w : density of water (g/cm^3)

The FE values are calculated for the test cases and shown on Table 4.

Table4 Filtration Efficiency

Case	FE(%)
1	As: 99.96, Pb: 99.99, PCB: 99.87
2	As: 99.92, Pb: 100, PCB: 100
3	As: 100, Pb: 100, PCB: 100
4	99.64
5	99.99
6	99.99

4.2.2 Containment Efficiency

The containment efficiency (CE) is determined as the ratio of the total amount of contaminants in the geo-tube to the injected amount of contaminants in the initial injected slurry.

$$CE = \frac{C_{initial} - C_{drainage}}{C_{initial}} \times 100 \cdots\cdots (3)$$

$$C_{initial} = c_{initial} \times Q \cdots\cdots (4)$$

$$C_{drainage} = \sum c_i \times q_i \cdots\cdots (5)$$

CE : Containment Efficiency (%)

$C_{initial}$: total amount of contaminants in slurry

$C_{drainage}$: total amount of contaminants in drainage

Q : total volume of Slurry

q_i : volume of drainage

The CE values are calculated for the test cases and shown on Table 5.

Table 5 Containment Efficiency

Case	$C_{initial}$ As (mg)	Pb (mg)	PCB (mg)	Dioxins (pg-TEQ)	$C_{drainage}$ As (mg)	Pb (mg)	PCB (mg)	Dioxins (pg-TEQ)	CE (%)
1	58.932	694.69	12.5	-	0.16987	2.6889	0.38236	-	As: 99.71, Pb: 99.61, PCB: 99.69
2	78.447	924.73	16.64	-	0.038	0.18607	0.015249	-	As: 99.95, Pb: 99.98, PCB: 99.91
3	626.29	7382.6	132.85	-	0.1314	0.177	0.02735	-	As: 99.98, Pb: 99.99, PCB: 99.98
4	-	-	-	268,610,000	-	-	-	1,309,000	99.51
5	-	-	-	270,790,000	-	-	-	468,200	99.83
6	-	-	-	10,723,000	-	-	-	19,420	99.82

4.2.3 Effect of content of contaminants

Comparing the values of CE in Case 5 and 6, it seems that the content of dioxins doesn’t affect the performance of geo-tube filtration. The content of contaminants in the soil may not affect CE.

4.2.4 Effect of flocculant

Comparing Case 1 and 2, it seems that the flocculant improves the performance of geo-tube filtration. Also, Case 4 and 5 show the same results. Adding flocculant was effective to enhance the geo-tube’s performance to retard the migration of contaminants.

5 CONCLUSION

The applicability of geo-tube method to contaminated sediment was studied. The following results were obtained.
(1) The contaminants in drainage from geo-tube rapidly decreased at the initial stage of the dewatering process.

(2) The CE value was defined for the evaluation of the performance of geo-tube for containment. The conclusion is as follows.
- The CE was greater than 99.8% when adding flocculant. The most of contaminants were successfully trapped in the geo-tube.
- The CE seems not affected by content of contaminants in the soil.
- Adding the flocculant improved the CE value.

It can be concluded that geo-tube method is an effective containment system for contaminated sediment. Geo-tube method can dewater high water-content contaminated soil with keeping contaminants inside the geo-tube.

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